ON THE ORTHOTROPY OF 3D-PRINTED POLYAMIDE 12

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Abstract: In this paper, the mechanical behaviour of a selective laser sintered polyamide 12 is studied, to assess whether there is an orthotropic nature, due to the way the material is manufactured. For this purpose, several dumbbell shaped specimens, according to the ASTM D-638, are manufactured and tested along the three print directions: edgewise, flatwise and upright. It can be concluded that although there are slight differences in mechanical properties, there is no significant orthotropy and the main difference is the lower failure stress and strain of the upright-printed specimens.

1. Introduction

3D printing, additive manufacturing, rapid prototyping, … are very popular terms these days. They all refer to the same family of production methods where parts are built layer by layer. Compared to traditional manufacturing techniques, they show immense promise in terms of flexibility, cost and waste reduction. At this moment, 3D printing is used in many applications, ranging from prostheses in the medical field to unique prototypes.

With respect to additive manufacturing, there are two big families: (i) selective deposition and (ii) selective binding. For the first class, the material is deposited in the desired geometry layer by layer on the printing bed and sometimes, structures necessary to support the final part, are added. An example of such a method is Fused Deposition Modelling (FDM). For the second class, there is an entire layer of material present, but only the desired geometry is bound locally. An example of such a method is Selective Laser Sintering (SLS) and this is the method considered for underlying research. With SLS, a LASER scans the surface of a bed filled with powdered material and the heat of the LASER melts or sinters the powder locally to form a binding. The material can be either metal or polymer, but for this research, the latter was chosen, namely polyamide 12.

As already mentioned, 3D printing is used for lots of applications, but they are only rarely considered for structural parts which carry high loads, mainly because the mechanical behaviour is not yet fully understood. One of the issues is whether the mechanical properties depend on the printing direction, meaning that the printed material would have an orthotropic behaviour. Figure 1 illustrates the definition of the three different printing directions, used for SLS and specifically for the dumbbell type specimens considered here. The LASER scans the xy-plane and the bed, and thus the printing direction, moves along the z-axis.

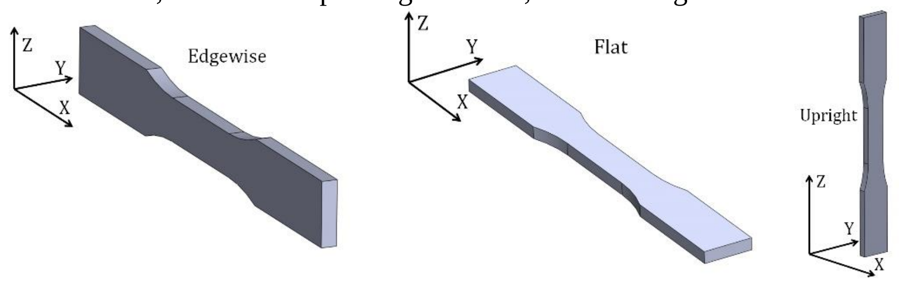

Figure 1. Illustration of the definition of the different printing directions used in this study

2. Experiments and results

A number of specimens from each of the three printing directions are then tested on a hydraulic INSTRON 8801 tensile machine, and the mechanical properties, such as Young's modulus, Poisson's ratio, failure stress and failure strain are derived. The tests are conducted in a displacement-controlled manner at a speed of 2 mm/min and Digital Image Correlation is used to measure the full displacement field and calculate the necessary strains. As the tensile machine is provided with an alignment cell, correct alignment of the grips is assured. Correct alignment was also verified using the displacement fields from the DIC measurements, to make sure that misalignment did not corrupt the data.

Figure 2 (a) shows the typical behaviour of the different printing directions; one specimen for each printing direction is chosen for clarity's sake. After a linear part, the material yields and then shows a significant non-linear part up till failure. The only significant difference between printing directions is the fact that upright specimen (U) fails a lot sooner than the other two. Although one might say that the flatwise specimen (F) is a little bit stronger than the edgewise (E), this is not the case when taking the scatter of all the tests into account. Figure 2 (b) gives an overview of the Young's moduli, derived for the [0-0.2%] strain range. An extensometer was also used for this purpose, but since it is difficult to ensure perfect alignment of this device with the loading direction, only the DIC measurements are considered. As such, it can be derived that there is no significant difference in tensile stiffness for the different printing directions.

a) b)

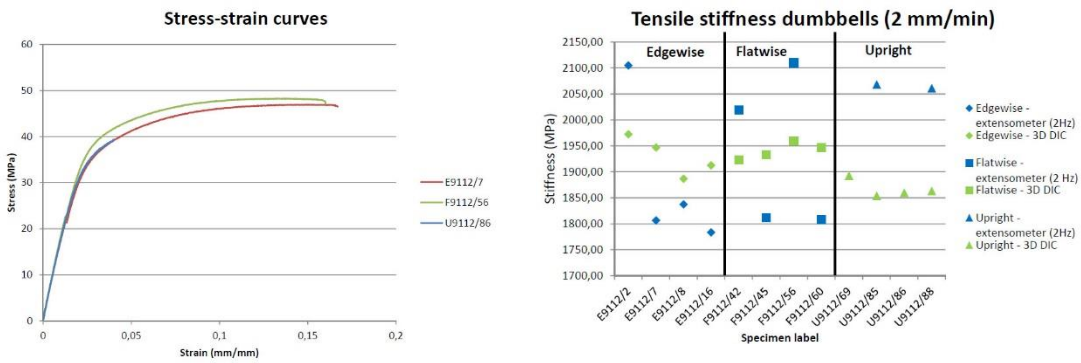

Figure 2. (a) illustration of the stress-strain curves for the different printing directions; (b) illustration of the Young's modulus for different specimens in different printing directions

3. Conclusions

Although the mechanical properties tend to differ slightly, our first impression is that the difference in stiffness between the edgewise, flatwise and upright printed specimen is more related to other effects, e.g. the position in the build and/or temperature history, rather than due to an inherent orthotropic behaviour of the material. The only significant difference between edge- and flatwise on one hand and upright on the other hand, is the failure behaviour. The upright printed specimen fails more brittle at a lower stress and a significantly lower failure strain, which is most likely caused by the separation of the sintered layers.

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